ADVANCE PROOF—(*Subject to revision*).

This proof is sent to you for discussion only, and on the express understanding that it is not to be used for any other purpose whatever.—(*See Sec. 47 of the Constitution*).

Canadian Society of Civil Engineers.
INCORPORATED 1887.
TRANSACTIONS.

THE DRY DOCK AT KINGSTON, ONTARIO.

By Henry F. Perley, M.Can.Soc.C.E.

To be read Thursday, 9th April, 1896.

To provide for the repairing of craft on the Great Lakes, the Government of Canada in 1889 commenced the construction of a dry dock at Kingston, Ont., which was brought to completion in 1892, the plans and specifications for which, excepting the details of the pumping plant and engine house, were prepared by the writer.

After an examination of several sites had been made, that known as "Power's Ship Yard" fronting on the harbour was selected, and purchased on reasonable terms. In addition to the property thus acquired, the lower portion of Union street, which had been closed some years previously under an arrangement for the construction of a dry dock, was ceded by the City to the Crown, which thus became the possessor of a frontage of 400 ft. on the harbour, a frontage having deep water at but a little distance from the shore.

The site is situated between Gore and Union streets, having the shops of the Kingston Locomotive Works on one side, and those of the Kingston Foundry Company on the other.

When taken possession of, the site was encumbered with several buildings, the remains of an abandoned marine railway, an old wharf, and the work that had been executed on a proposed dry dock and abandoned, all of which had to be removed.

In determining the dimensions of the dock, it was judged that they should exceed by a small amount those of the locks on the Welland canal, so that any vessel which could pass through them could be admitted to the dock, and a length of 280 ft. on the floor and 48 ft. width of entrance were adopted. During construction, representations were made, that the width of the entrance was not sufficient to admit some paddle-wheel steamers plying on Lake Ontario, and it was increased to 55 ft., such change involving the widening of the body of the dock, increasing the size of the caisson and the dimensions of the caisson chamber.

After cleaning the bottom in front of the site, an earthern coffer-dam was placed, the material (clay) composing it being obtained from the channel of the Cataraqui through the marsh above the highway bridge. This dam failed when the work was about one-third completed, but the break was easily filled and the work resumed.

The dock is built of limestone obtained from quarries at Belleville, and fully up to the requirements of the specification, which demanded that the ashlar in the altars except in two instances, should be built of stones 2 ft. 8 ins. in height. As stretchers could not be less than 4 ft. in length with a bed not less in width than $1\frac{1}{2}$ times the rise, the smallest stone that could be used weighed over three tons. The coursing of the sidewalls was carried through the body of the work, the whole with $\frac{1}{4}$ in. joints, and dressed with the fine end of a Bouchard hammer. The backing consisted of large and well-shaped stones of such thickness, that *two* courses were equal to *one* course of face-work. The floor is of stone, the central 6 ft. carrying the keel-blocks being

raised 6 ins. above the dock bottom. The foundation of the engine house, chimney and machinery were carried up from the rock, and the floors paved with stone.

A quantity of concrete was used, composed of 6 parts of broken stone, 1 part clean, sharp sand, and 1 part of Portland cement.

The whole of the masonry was laid in a compound of *one* of Portland cement to *two* of sand, mixed and used as required, each course being grouted up and filled full with the compound. All joints were lipped for 4 ins. from the face with a compound of 1 of cement to 1 of sand, and neatly pointed and finished off when green.

Only Portland cement was used in the work, and a constant testing was carried on during construction. Samples were taken from every *tenth* barrel as delivered, and tested for fineness by the whole sample passing through a 2,500 sieve. Briquettes of neat cement, after remaining for twelve hours in the air and seven clear days in water, gave an average tensile strength of 445 lbs. per square inch.

The quoins of the outer face of the inner invert and side walls are of grey granite, all remaining stones in the invert being of limestone. The granite and limestone quoins facing on the caisson berth, and of the walls on either side, are worked with a projection of $\frac{3}{4}$ in., and a full width of 12 ins., and set absolutely perpendicular and in a true plane, the faces being finely axed and rubbed down, for on these meeting faces depends the tightness with which the caisson fits, thus preventing leakage when the dock is empty.

An extension of the caisson-berth forms a chamber into which the caisson is drawn to admit a vessel. Along each side of the bottom are heavy cast iron rollers placed at intervals, on which the caisson rests and travels when being moved.

The width of the inner invert is 55 ft, and of the outer invert 57 ft., this difference being necessary to permit the caisson being floated into its berth. They are built to a radius of 193 ft., and the stones forming them are cut with radial joints. The lowest point in the inverts is 15 ft. 6 ins. below zero, or the assumed average low water level of the lake, 22 ft. below coping level, and 4 ft. 6 ins. above the floor of the dock.

Outside the outer invert is an apron of stone 20 ft. in width, and 2 ft. lower than the centre of the invert, in which are placed granite blocks on which the caisson can rest if at any time it is found expedient or necessary to effect repairs in the caisson berth or chamber, or to dock a vessel longer than the floor of the dock, or, in other words, a vessel of 310 ft. in length.

Under the foundation of the dock bottom are arterial drains, by means of which the leakage from the lake is carried to and discharged by the auxiliary pump, when the dock is empty.

Access is had to the dock floor by steps on either side at the entrance end, and on either side of the timber slide at the head.

In the floor at the lake end is a rudder well, 24 ft. long, 3 ft. wide, and 12 ft. deep, which has proved of much service, as it permits an easy removal and replacing of a rudder.

Sixteen (16) cast-iron mooring parts, set in and filled with concrete, are placed around the dock, together with *six* heavy, double purchase capstans. On the dock floor are cast-iron keel-blocks capped with hard wood, placed at intervals of 5 ft., and 32 bilge-blocks at 10 ft. centres, which are operated from the dock coping.

The dock is filled through a culvert 4 ft. in diameter, the mouth of which is outside the entrance works, and the discharge over the inner invert, the whole being submerged 6 ft. below zero, and controlled by a 4 ft. cast-iron valve. Provision has been made whereby, in an emergency, filling can take place through the emptying culvert, which is also 4 ft. in diameter and controlled by a valve. The caisson chamber and berth is connected by a 12 in. pipe with the auxiliary pump, so that either can be emptied in the event of the stop-logs being put in place.

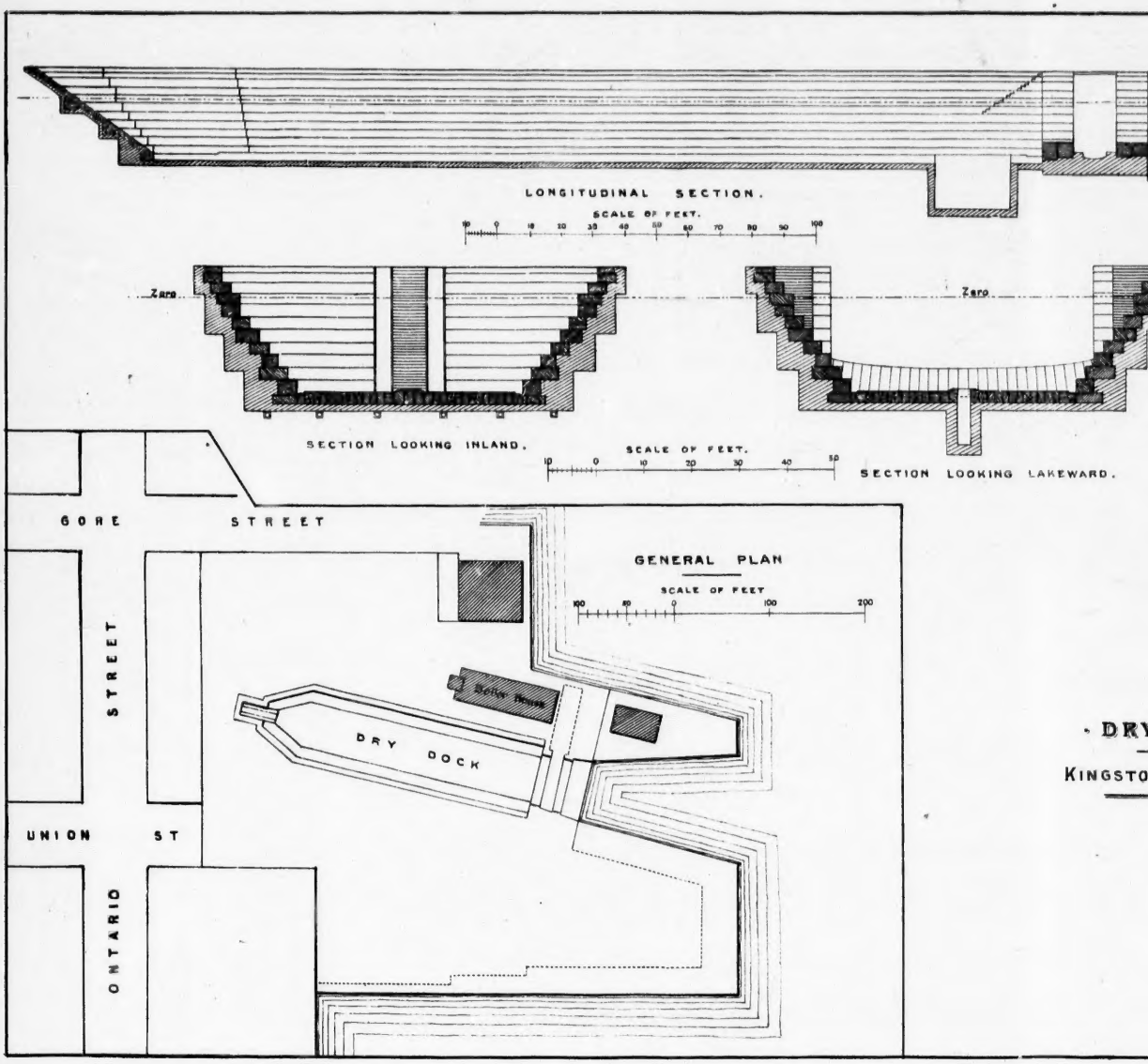
The engine-house, which comprises an engine-room, boiler-room and

dynamo room, is of stone. The chimney—also of stone, and 90 ft. in height, is placed partly within and partly without the building. Over

repairs.

The dock is closed by a caisson, built of steel, which may be described as an irregular rectangular box with parallel sides and inclined ends, measuring 57 ft. in length on the inner face, and 59 ft. on the outer; 11 ft. 10 ins. in width; and 21 ft. 6 ins. in height. Two keels, 4 by 8 ins. dimensions, run the whole length of the bottom, on the outer edges of which are inserted at regular intervals, 4 by 4½ ins. shear

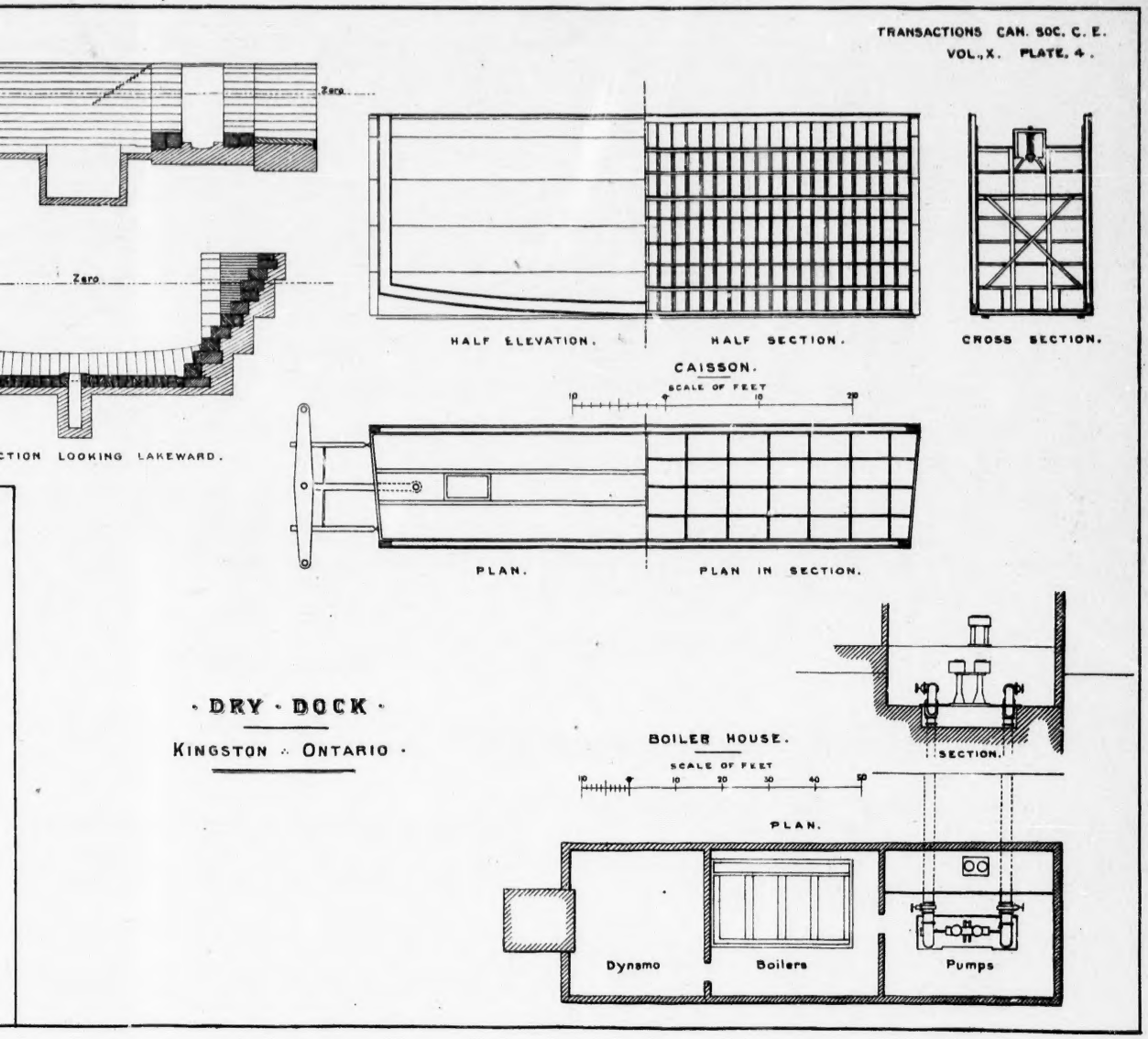
raised 6 ins. above the dock bottom. The foundation of the engine house, chimney and machinery were carried up from the rock, and



a 4 ft. cast-iron valve. Provision has been made whereby, in an emergency, filling can take place through the emptying culvert, which is also 4 ft. in diameter and controlled by a valve. The caisson chamber and berth is connected by a 12 in. pipe with the auxiliary pump, so that either can be emptied in the event of the stop-logs being put in place.

The engine-house, which comprises an engine-room, boiler-room and

dynamo room, is of stone. The chimney—also of stone, and 90 ft. in height, is placed partly within and partly without the building. Over



repairs.

The dock is closed by a caisson, built of steel, which may be described as an irregular rectangular box with parallel sides and inclined ends, measuring 57 ft. in length on the inner face, and 59 ft. on the outer; 11 ft. 10 ins. in width; and 21 ft. 6 ins. in height. Two keels, 4 by 8 ins. dimensions, run the whole length of the bottom, on the outer edges of which are inserted at regular intervals, 4 by 4½ ins. shear

raised 6 ins. above the dock bottom. The foundation of the engine house, chimney and machinery were carried up from the rock, and

a 4 ft. cast-iron valve. Provision has been made whereby, in an emergency, filling can take place through the emptying culvert, which is also 4 ft. in diameter and controlled by a valve. The caisson chamber and berth is connected by a 12 in. pipe with the auxiliary pump, so that either can be emptied in the event of the stop-logs being put in place.

The engine-house, which comprises an engine-room, boiler-room and

dynamo room, is of stone. The chimney—also of stone, and 90 ft. in height, is placed partly within and partly without the building. Over the engine and the dynamo rooms the roof trusses are of wood, and over the boilers of iron, the party walls being carried up to the roof as a safeguard in the case of fire.

The major portion of the floor of the engine room is 6½ ft. below zero, or 13 ft. below coping level, and on it is placed the pumping plant, which consists of two vertical 18 ins. centrifugal pumps, one right-handed the other left-handed, having discs 4 ft. 8 ins. in diameter, each operated by a vertical, high pressure engine, having cylinders 18 ins. in diameter, and a stroke of 18 ins. The pumps are connected directly with the engines and are in line; and by means of clutches they can be geared together so that *one* engine can drive both pumps, or an engine can drive the opposite pump.

The suction pipes, which are 22 ins. in diameter, are furnished with foot-valves, and are led through the engine room floor to the pumps, all joints being absolutely water-tight. The pumps discharge through 22 in. pipes, the centres of which are 9 ft. below coping level, or 2 ft. 6 ins. below zero, and when the lake is at that level, the pumps operate against a head of that height. To prevent inflow when the pumps are not in use and the dock is empty, each discharge pipe is provided with a 22 in. valve.

The auxiliary pump and engines are placed on the upper or higher portion of the engine room floor. This pump, which is an 8 in. horizontal centrifugal, has a maximum lift of 31 ft. 6 ins., and discharges 3 ft. above zero. It is operated by a pair of vertical, high pressure engines, having 12 in. cylinders and 12 in. stroke, which are also used to move, by means of intermediate gearing, the caisson into and out of place. On the lower floor of the engine room is a "Knowles" fire pump, the steam cylinder being 15 ins. and the water cylinder 10 ins. in diameter, both having a stroke of 21 ins. This pump can be used in the event of the auxiliary pump being disabled. A delivery pipe is carried to the outside of the building, having a proper cap for attaching *four* lines of 2½ in. fire hose.

A "Knowles" patent duplex boiler feed pump, with steam cylinder 6 ins., and water cylinder 4 ins., and stroke 7 ins., is placed in the boiler room.

The boilers—four in number—are of the cylindrical, multi-tubular type, set in brick work, with all the fittings and appliances for their successful working. They are 14 ft. long and 5½ ft. in diameter, each containing 84, No. 9, W. G., lap welded, charcoal iron tubes, 3½ ins. external diameter, and furnished with domes 3 ft. high and 2½ ft. diameter. The shells and ends are of ⅝ steel, the longitudinal seams being lapped and double rivetted, the circumferential seams lapped and single rivetted. Before acceptance they were subjected to a cold water test of 180 lbs. per square inch, the working pressure being set at 100 lbs. Two of these boilers supply steam enough for the main engines. The smoke flue runs along the front end of the boilers, where connection is made with the uptakes, and is carried to and through the party wall of the dynamo room, when it is led downwards and under the floor to the chimney.

A boiler of the drop flue type, 9 ft. high and 4 ft. in diameter, with 270 1¼ ins. by 18 ins. flues, with circulating tubes, is placed in a corner of the boiler room, and supplies steam to the auxiliary engines which can also take steam from the main boilers.

A travelling crane to lift 3 tons has been placed in the engine room, and with it any part of the engines or pumps can be handled for repairs.

The dock is closed by a caisson, built of steel, which may be described as an irregular rectangular box with parallel sides and inclined ends, measuring 57 ft. in length on the inner face, and 59 ft. on the outer; 11 ft. 10 ins. in width; and 21 ft. 6 ins. in height. Two keels, 4 by 8 ins. dimensions, run the whole length of the bottom, on the outer edges of which are inserted at regular intervals, 4 by 4½ ins. shear

steel bars, properly bent, their places in the keels being truly planed to the required curvature. The keels rest on the rollers in the caisson berth and chamber, and the curved bars, which project somewhat beyond the sides of the keels, are for the purpose of preserving the parallelism of the caisson while being moved. The lower 3 ft. is of cellular construction for strength and stiffness, and composed of $\frac{1}{2}$ in. plates and $3 \times 3 \times \frac{3}{8}$ ins. angles. All angles for the sides and ends are $3 \times 3 \times \frac{1}{2}$ in., and for the reverse bars $3 \times 3 \times \frac{3}{8}$ in. The cross-beams up to the lower dock are $4 \times 4 \times \frac{1}{2}$ in. angles, and above $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ in. Under the lower and upper floors, Z beams $5 \times 3\frac{1}{16} \times 2\frac{3}{4} \times \frac{1}{2}$ in., were used. The upright posts are $6 \times 3 \times \frac{3}{8}$ in. channels, and the diagonal braces, $4 \times 3 \times \frac{1}{2}$ in. angles. The plates in the bottom and first row on the sides and ends are $\frac{1}{2}$ in. in thickness, and those above diminish to $\frac{1}{4}$ in. in the top plate, which is finished with a $9 \times \frac{3}{8}$ in. bulb. The floor plates are $\frac{1}{2}$ in. in thickness. All outside plates were planed on their edges, and lapped $2\frac{1}{2}$ ins. in the work, and were single rivetted. Where required, filling pieces were placed between the plates and the frames, to make up for the difference in the thickness of the plates, and voids between the plates and the frames.

For the movement of the caisson a hauling bar 13 ft. 4 ins. in length is connected by means of a 4 in. pin, the outer end projecting 7 ft. 9 ins., and carrying a yoke 17 ft. 8 ins. in length attached by a 4 in. pin, the outer ends being supported by two hinged brackets coupled with parallel motion bars.

For ballasting purposes, *two* 3 in. sluice valves are placed in the outer face above the line of the upper floor, to which are attached 6 in. cast iron pipes leading to within $4\frac{1}{2}$ ft. of the bottom. At the bottom of the inside face a 4 in. valve is placed to drain the caisson when the dock is empty; and the caisson can also be emptied by a No. 5 pulsometer.

The cellular bottom is filled with concrete, and the further permanent ballast is supplied by the requisite amount of stone.

On the outer faces are rivetted $6 \times 6 \times \frac{1}{2}$ in. angles, which carry the white oak meeting faces, which are secured in place by $\frac{3}{4}$ in. bolts.

The caisson weighs 255,000 lbs., and when the lake is at zero its displacement is 358 net tons. It is moved into and out of place by wire ropes, which pass over traversing grooved wheels secured to the masonry at the dock end of the chamber, and over spirally grooved drums keyed on a horizontal shaft at the head, which is actuated by the auxiliary engines.

The dock at zero contains 2,100,000 gallons of water when unoccupied by a vessel, and can then be emptied in 75 minutes, the pumps and engines making 175 revolutions per minute, each pump thus throwing 14,000 gallons per minute. Through the filling culvert the dock can be filled in 55 minutes.

A large portion of the dock property as it stands to-day is made ground, the area being enclosed by crib-wharfing of the usual type, and filled with the materials excavated in grading the site, and from the dock pit.

The cost of the dock may be placed as follows:—

Land	$ 20,000.00
Dock proper	365,000.00
Pumps, engines, etc	26,000.00
Engine house	26,000.00
Caisson	18,000.00
Engineering and contingencies	42,000.00
Total	$497,000.00